

ARCHITECTURAL TERRA COTTA

BY

WM. F. LOCKHARDT

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By WM. F. LOCKHARDT
Secretary-Director
National Terra Cotta Society

The terra cotta which is today proving itself so admirably adapted to the varied architectural demands of the "moderne" in architecture had its origin millenniums past, in prehistoric clay-working. Terra cotta thousands of years old is treasured in modern museums that are themselves clothed in terra cotta more colorful, more beautiful in line and form, and certainly more enduring, than anything the ancient world has bequeathed to us.

Color in architecture the ancients knew principally as polychromy—the use of several colors on one design or portion of the work. We have many outstanding modern examples of polychromy, such as the Philadelphia Museum, classical in architecture and coloring, for which terra cotta was used as it would have been ages ago.

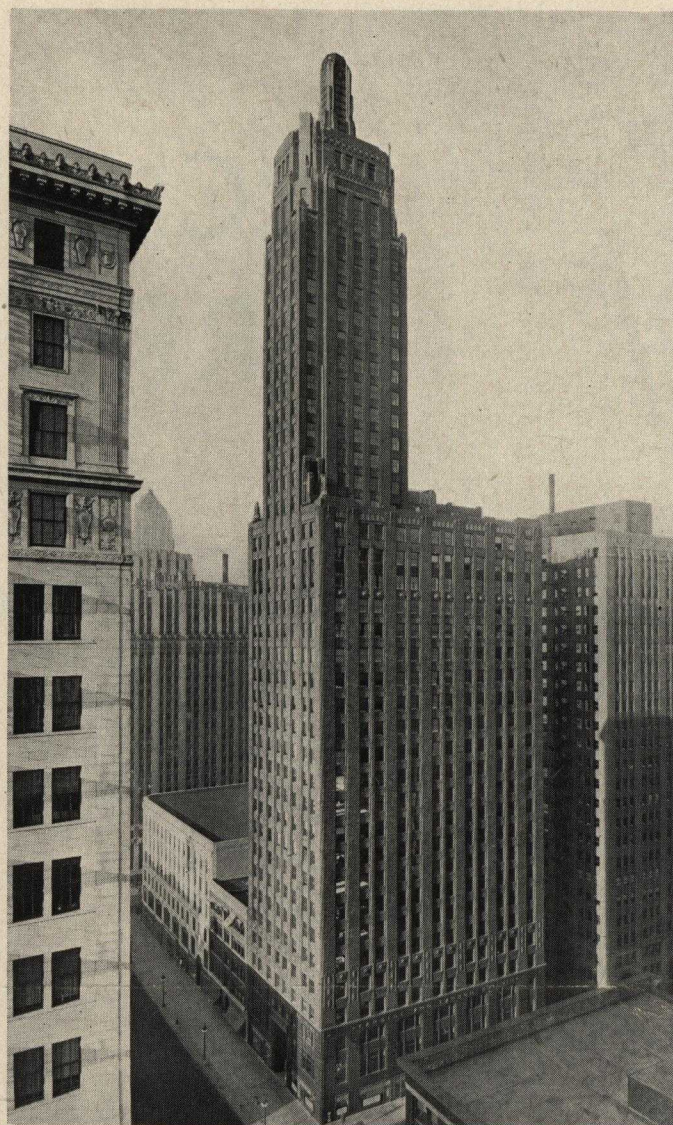
In this twentieth century, terra cotta's distinctive contribution to architecture has been to furnish solid color on an unapproached scale—the 38-story green mass of the Carbide & Carbon Building in Chicago, or the turquoise blue Pelissier and Eastern Outfitting buildings in Los Angeles, to name a few among many.

Ancient Greece had no smoke problem, with thousands of offices, factories, locomotives and steamships to fill the air with soot and dim the beauty of its terra cotta art. Yet today terra cotta is the recourse of the modern owner with a building to keep clean and attractive to prospective tenants under the most adverse conditions.

Daylight there was, enough for all, in those times; today we are glad to know that by facing a building with terra cotta we may increase the light in the street over 50 per cent as compared with that resulting from the use of certain other architectural materials. And history fails to record any system of floodlighting on the Acropolis, while today we lean heavily on the proven superiority of terra cotta for buildings to be given exterior night illumination.

No Athenian Noise-Abatement Commission sought to rout the man with the riveting gun, for the Parthenon had no complicated structural skeleton. But today terra cotta, shaped while plastic to conform to difficult structural conditions, continues to offer beauty as well as economy and endurance.

Although rooted back by direct line into the dim reaches of antiquity, the terra cotta of the early part of the twentieth century probably showed no greater



CARBON & CARBIDE BUILDING, CHICAGO, FACED WITH GREEN
TERRA COTTA WITH GOLD RELIEF

advance over the crude baked clay of ancient Greece than the terra cotta of 1930 over that made a generation ago.

From almost every standpoint, such as technical excellence in ceramics, and in construction methods, great strides have been made. It is with the latter that the contractor most obviously is concerned, for it is with the construction of terra cotta that he deals, and if his work is to be enduring and satisfactory to the owner—and thus to himself—his knowledge of approved methods of terra cotta construction must be up to date and practically applied.

Yet, as ceramic excellence also plays an important part in the eventual performance of the ware in service, the builder should be permitted to peep behind the scenes and learn something of the fabrication of the material. It cannot be emphasized too strongly, however, that the major reliance for satisfactory performance rests upon the builder, and that too high a percentage of complaints has been traced to construction, as distinct from manufacturing.

Literally, terra cotta signifies "baked clay," and clay which has been baked or fired is, as is well known, practically unrivalled in its ability to withstand the ravages of time. The first terra cotta was undoubtedly an outgrowth of the primitive brick-making art in those countries bordering the Mediterranean which were the cradles of modern civilization. Our knowledge of the Babylonians is due largely to their tablet-records of clay which alone have survived the passage of the countless intervening centuries. Much of what we know of other old peoples all over the globe has likewise been obtained through the study of their burnt-clay ware, which has come down the ages practically intact, although their buildings and their objects of daily use have long since moldered to dust.

The clay or clays from which terra cotta is made are carefully selected for certain definite physical properties. In many cases the "body" finally used is a mixture of different clays from widely scattered sources, all accurately measured and combined to exact formulas. As an aid in controlling shrinkage, about one-third of the mixture is composed of previously fired clay which has been ground to suitable size. This grit is technically called "grog."

Architectural terra cotta is not stocked by material dealers. It is made for each job individually and with reference to the structural conditions to be met thereon. More so than any other architectural product, terra cotta is "hand-tailored" to the finest degree—not simply the embodiment in three dimensions of a set of drawings, but the complete expression of an architectural idea in terms of a certain combination of colors, glazes, surface textures, ornamentation, and other qualities not found combined in other masonry materials. To achieve this result in a complicated product a high degree of organization is necessary. The sequence of manufacturing operations may be summarized as follows:

The architect's complete scale drawings and steel framing plans are furnished the manufacturer. Following the design, the latter then makes shop drawings to an appropriate scale showing the jointing and construction and, where necessary, full-size details to the proper "shrinkage scale." As the clay shrinks in the drying and firing operations about one inch in thirteen, the terra cotta draftsman uses a scale or rule thirteen inches long, divided into 12 "inches," to insure the finished ware being the intended size after shrinkage has taken place.

The drawings have to be models of clarity, in order that they may be interpreted quickly and accurately by all who have to use them—modelmaker, fitter, shipping department, and contractor's foreman. Each part of the building is designated usually by a letter prefix, and each individual piece of terra cotta is numbered to indicate its exact position in the finished structure. Systems of numbering vary slightly with



MODELING ROOM OF A TERRA COTTA FACTORY



PLASTER SHOP FOR PLASTER OF PARIS MODELS WHICH DO NOT REQUIRE SPECIAL ORNAMENTATION



GENERAL VIEW OF PRESSING SHOP WHERE CLAY IS PRESSED INTO THE MOLDS

different manufacturers, but all are easily understandable.

The speed and accuracy with which the terra cotta drawings are prepared is always appreciated by the builder, as the time consumed by subcontractors in the preparation of shop drawings is a matter of importance. The irksome and expensive delays attendant upon hand-to-mouth production of shop details must be avoided.

A typical setting drawing is shown in Fig. 2. In this drawing it will be seen that each course which differs in some particular from other courses has been given a separate letter, and that all pieces in that course which are alike carry the same number, while pieces which are unlike others have different numbers. This reduces the number of identifying marks which the workmen have to sort over to find the piece wanted. This system of numbering can be used where any piece of a given size (and therefore, number) can be substituted for any other similar piece.

Where the pieces have all been fitted to insure exactness of construction, or a matched color scheme, they are then individually numbered, and must be set in the order shown and not otherwise, even though apparently of the same size and color. Pieces so numbered cannot be interchanged without injuring the appearance of the finished work.

After these drawings have been approved by the architect, full-size models to shrinkage scale are made of plaster for each different shape shown on the shop drawings. Over these models sectional molds of plaster are cast, from which latter the required number of pieces of terra cotta are produced.

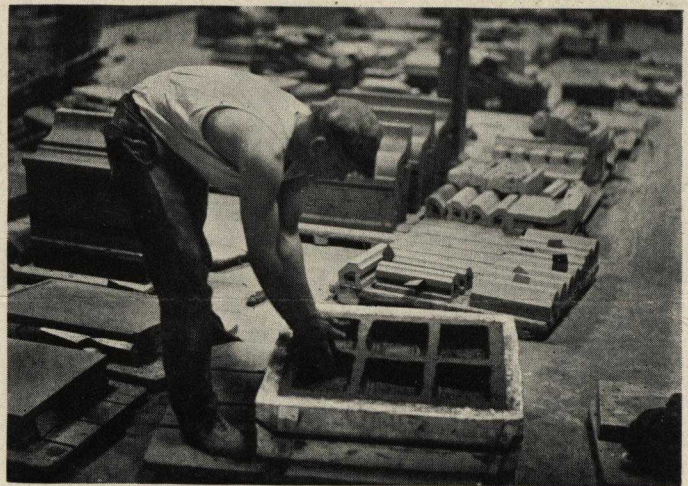
Where the architect's drawings call for ornament, it is modeled in clay. Photographs of the ornament as modeled are submitted to the architect for approval, or he may examine the models personally at the factory—the soft clay permits of any corrections or improvements which may be desired.

In the case of small pieces of ornament on a plain surface, such as a rosette, the clay model usually is built into the face of the plaster model. Large designs are modeled on easels, and after approval are cut into pieces of the desired shapes and sizes. Where only one piece of a kind is involved, such as a special urn, or a gargoyle, it may be modeled directly in the terra cotta clay, and the original model itself fired after it has been approved.

The foregoing processes are preparatory to the actual manufacture, the first step in which is "pressing." This consists of shaping the plastic clay in the molds. The walls of the pieces are usually about an inch thick, and follow the contour of the molds. The partitions are of such thickness and are so spaced as to give the necessary strength and stability. The pressed piece remains in the mold for a short time while the clay stiffens due to a slight drying. It is then removed, retouched if necessary to correct any



DETAIL OF PRESSING OPERATION



PRESSING IN THE STIFFENING WEBS.



HAND COLORING FOR POLYCHROME WORK

accidental blemishes, and placed in driers to evaporate the moisture.

Where any element of the design is to be repeated, the one mold may be used to press a large number of identical pieces. Proper designing and detailing will often make possible extensive duplication, which explains why terra cotta, although a highly finished, handmade product, is frequently less costly than other materials which do not offer the architect the same scope for the exercise of his creative genius.

After drying, the terra cotta passes to the spraying department, where by means of compressed air apparatus, the exposed surfaces of the terra cotta are covered with the ceramic mixture which, during the firing develops the desired color or glaze.

The firing, which is the next step in the manufacturing sequence, is done in kilns where the temperature is brought up gradually to 2,000° F. or more, depending upon the characteristics of the clay and the glaze. After several days, the kiln is allowed to cool slowly to normal temperature, causing a slow annealing of the terra cotta. During the firing process the ware is not exposed directly to the flames, the kilns being known as the "muffled" type, wherein the flames and combustion gases pass through flues in the walls without touching the terra cotta.

From the kiln, the terra cotta goes to the fitting department where, when necessary, the joints are squared or cut to proper alignment or size. Careful fitting before shipment and proper numbering are really the manufacturer's last opportunity to insure a perfect job; from that point on public judgment as to the character of his material depends on the care and skill of the builder.

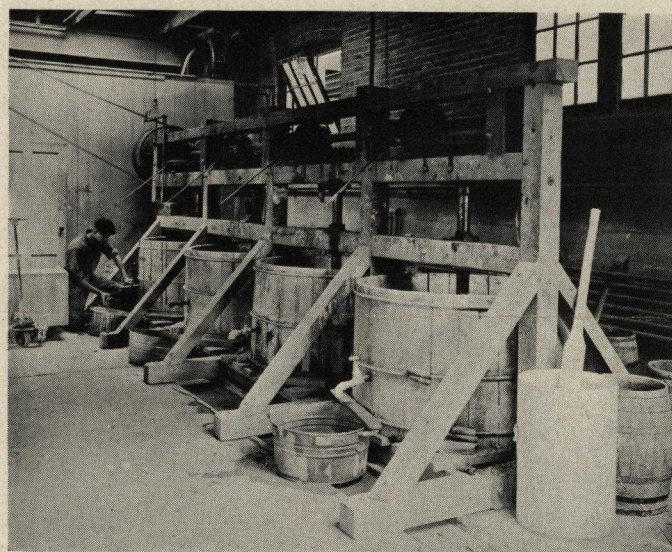
For rail transportation, terra cotta usually is shipped in bulk, securely packed in hay, and braced in the car to prevent shifting. For export by vessel, it may be packed in boxes or in crates, according to the conditions to be encountered. Upon arrival at the building site, the hay should be removed and the terra cotta placed in piles on wooden strips in the order marked on the pieces.

Up to about thirty years ago terra cotta was made in only two colors—unglazed red and unglazed buff. At the present time the body is usually of a buff-burning clay, while by surface treatment practically every color used in architectural work can be obtained. Certain colors, such as vermilion and vermilion-orange, and the metallic finishes—gold and silver—require a second firing and are therefore somewhat more expensive.

These metallic finishes deserve more than a passing word. With the development of new architectural styles and the creating of an entirely new system of ornament, metals are playing a part of constantly increasing importance in architecture. Metallic finishes are attained easily in terra cotta, with textures which would be difficult or impossible to obtain in the metals themselves. This is important for effective



CORNER OF THE LABORATORY WHERE GLAZES AND COLORS ARE PREPARED IN ADDITION TO EXPERIMENTAL WORK WHICH IS CARRIED ON



PREPARING THE GLAZES WHICH ARE TO BE SPRAYED ON EACH PIECE



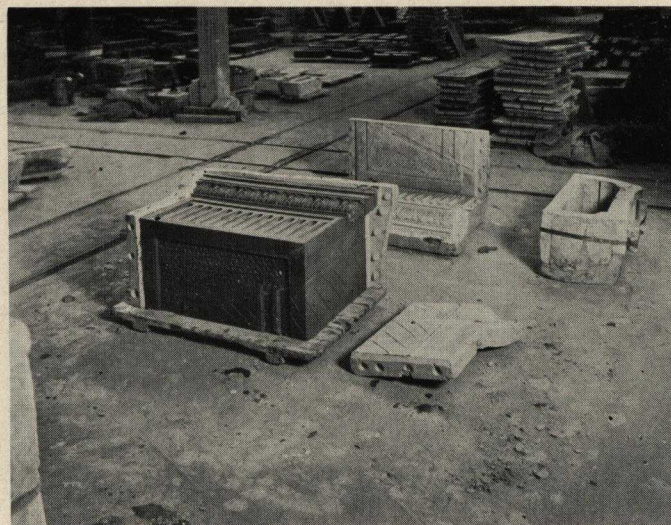
GENERAL VIEW OF THE KILN YARD WHERE THE TERRA COTTA IS BAKED

flood-lighting. Furthermore, expensive polishing is not needed to maintain their brilliance. Simple washing with soap and water will restore the metallic surfaces to seeming newness.

All building materials serve best when used with adequate knowledge of their properties and possibilities. For a number of years the terra cotta industry has maintained a Fellowship at the National Bureau of Standards in Washington, D. C., where a staff of experienced ceramic engineers have been devoting their entire time to practical research. This work has not been confined to the laboratory alone, but has included field inspection of thousands of buildings of varying ages and types of construction from coast to coast, and from Toronto to the Mexican line. From the mass of evidence thus accumulated, supplemented by thousands of tests and experiments, the industry can speak with conviction regarding the use of its product.

Satisfactory performance of masonry generally is dependent upon three major factors (aside from the nature of the masonry material itself) i.e., adequate support, proper anchoring or bonding, and keeping out water. The nature of the material with which we are dealing is established. Terra cotta has long since proved its durability. There stands beside the writer's desk as he works a piece of terra cotta from the old Tacoma Building in Chicago—the world's first skyscraper, nearly a half-century old when demolished. The lightest touches of the modeler's tools are defined as clearly after nearly fifty years' exposure to Chicago's none-too-mild climate as when the piece was made. Since the Tacoma Building was built, experience and research have improved the product immeasurably, so that as we deal with the three subjects previously mentioned we will not only discuss construction methods, but show how the product itself has been improved constantly for better performance.

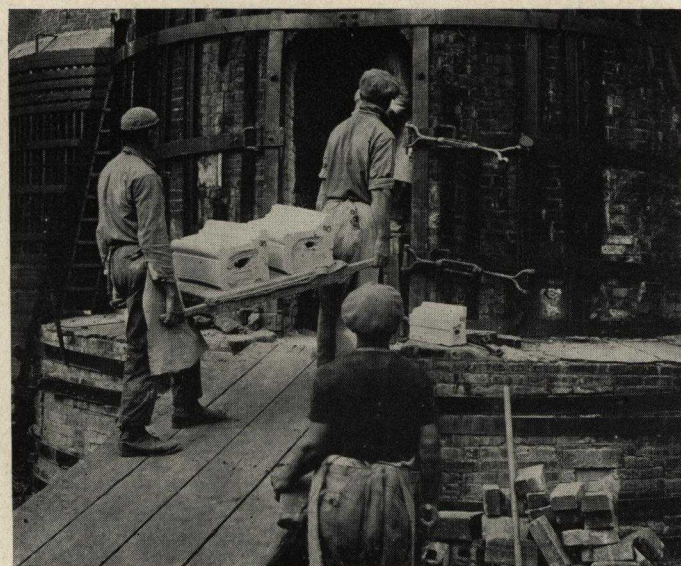
In concrete or steel-framed buildings, the terra cotta facing should be supported at each floor level fully and continuously on shelf supports of adequate strength and stiffness, rigidly connected to the structural frame. Steel shelf angles should in all cases be located in the mortar joints, and the terra cotta is so designed that this can be done. If, through carelessness in setting either the terra cotta or the steel supports, the shelf angles do not come in the proper position, promiscuous cutting of the webs in the terra cotta will cause trouble for two reasons: the terra cotta itself will be unduly weakened, and as the piece thus weakened will probably not be properly supported, the load that it should transfer to the shelf angle will be transmitted to the story below. Such a condition, observation shows, tends to become cumulative until one course of terra cotta and one shelf angle are carrying four or five or more stories instead of the one originally contemplated. Aside from the likelihood of cracking a piece weakened by careless cutting, deflection of the overloaded shelf angle is likely to



REMOVING THE MOLDS AFTER PRESSING



APPLYING THE GLAZES BY THE SPRAYING PROCESS



LOADING THE KILN

result in damaged masonry. The writer has seen examples of this type of failure in every architectural material in cities all over the country. Care in setting is the only remedy.

With buildings both as high and as long as they are today, expansion joints and pressure relieving joints are important to prevent the development of destructive stresses caused by deflection, wind pressure, temperature changes, settlement, and similar forces which assume considerable magnitude and which the masonry shell of a modern building is not intended to withstand. The manufacturer of a corrugated lead pressure relieving joint recommends that it be installed in alternate stories, at a point between three and seven feet below the shelf angle.

Where the architectural design is such that it might weaken a piece of terra cotta, the webs today are made heavier, and quite frequently intermediate webs are pressed in to further strengthen the piece. This is shown in Fig. 1. Because of this fact and the normally high crushing strength of vitrified clay, structural failures today are comparatively rare and when found are almost always conclusive evidence of grossly careless setting.

Setting mortars are usually 1 part cement to 3 parts sand, with not to exceed $1/5$ sack of hydrated lime per sack of cement. Richer mortars, while favored by the mason because they are "fatter," shrink excessively and should be avoided.

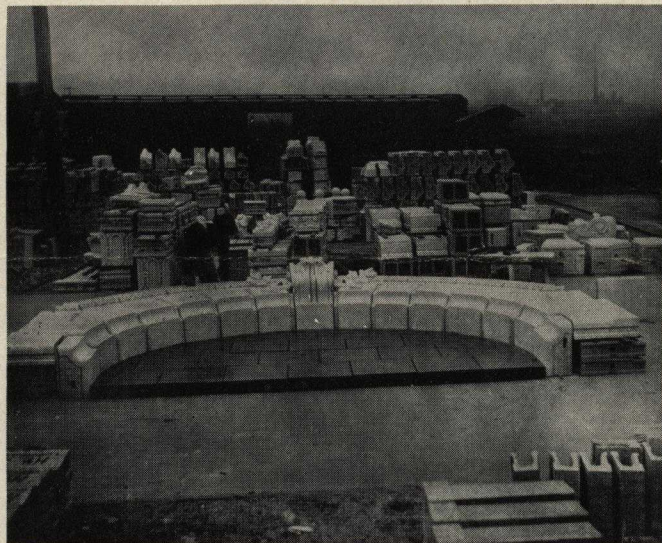
It is considered today to be better practice to strike the joints as the work progresses, instead of raking and tuck-pointing afterward as was formerly done. Mortar used for tuck-pointing is invariably of a different composition from the original setting mortar, and as a result expands and contracts at a different rate, disintegrates, and is of little permanent value.

In the matter of anchoring and bonding, construction practice varies considerably in different parts of the country, partly owing to the presence or absence of frost during part of the year. In all cases the manufacturer's recommendation is the safest guide, as he is most intimately in touch with the performance of his product when used as he suggests, and it is most directly to his interest to see that it is correctly installed.

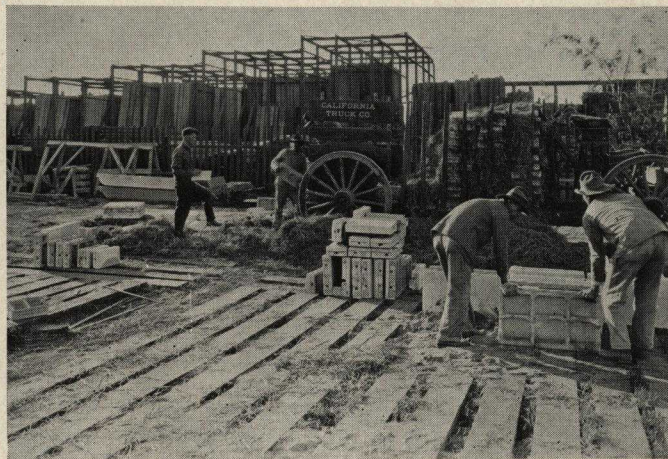
Generally speaking, approved practice is to fill the terra cotta by bonding the backing brick into it, as far out as the face of the wall. Where pieces project to any extent beyond the wall line, experience has proved that it is difficult if not impossible to fill the voids, which then remain to collect moisture (through either condensation or faulty joints or pointing) and cause trouble by freezing. Good design today provides vent-holes in the webs of such pieces and insures drainage by adequate weep-holes wherever there is any possibility that moisture may be entrapped. This is shown in Fig. 3, which is a vertical section through a typical wall.



PLACING THE PIECES IN THE KILN REQUIRES CARE TO PREVENT DEFORMATION DURING THE FIRING PROCESS



AFTER THE TERRA COTTA IS REMOVED FROM THE KILNS IT IS FITTED AND CHECKED BEFORE SHIPPING



RECEIVING THE TERRA COTTA AT THE BUILDING. IT SHOULD BE STACKED ON A PLANKED SURFACE

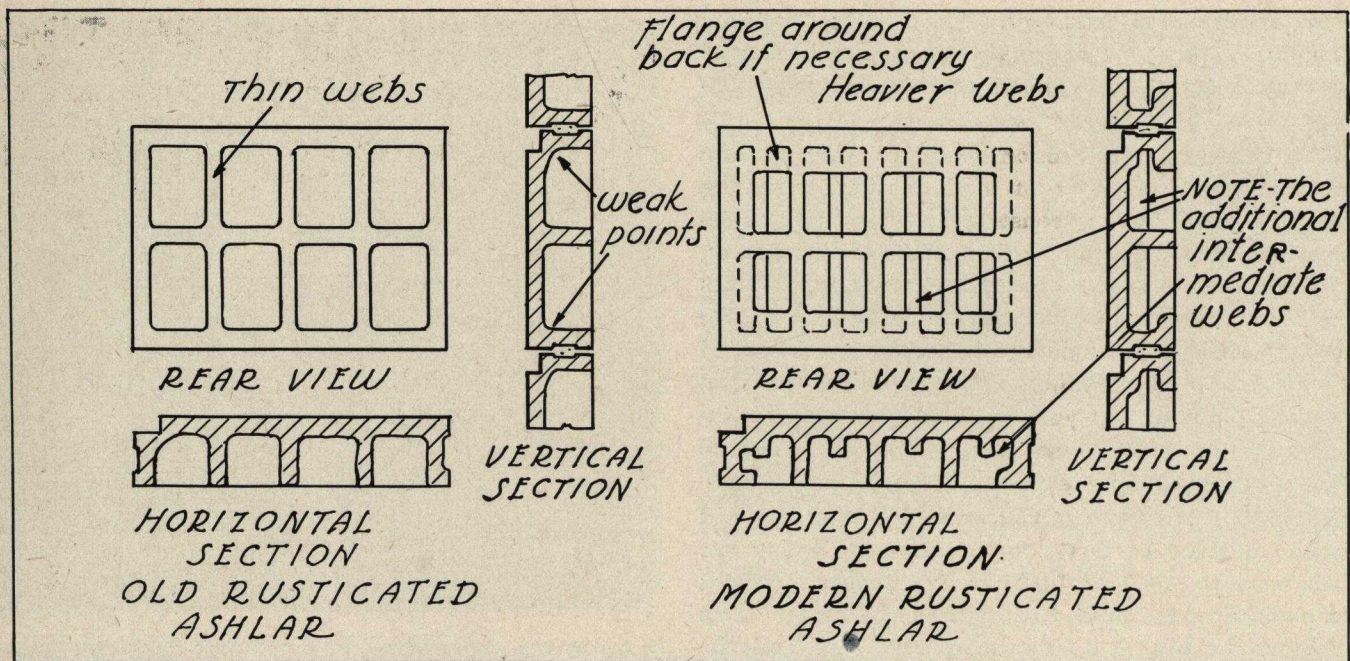


FIG. 1

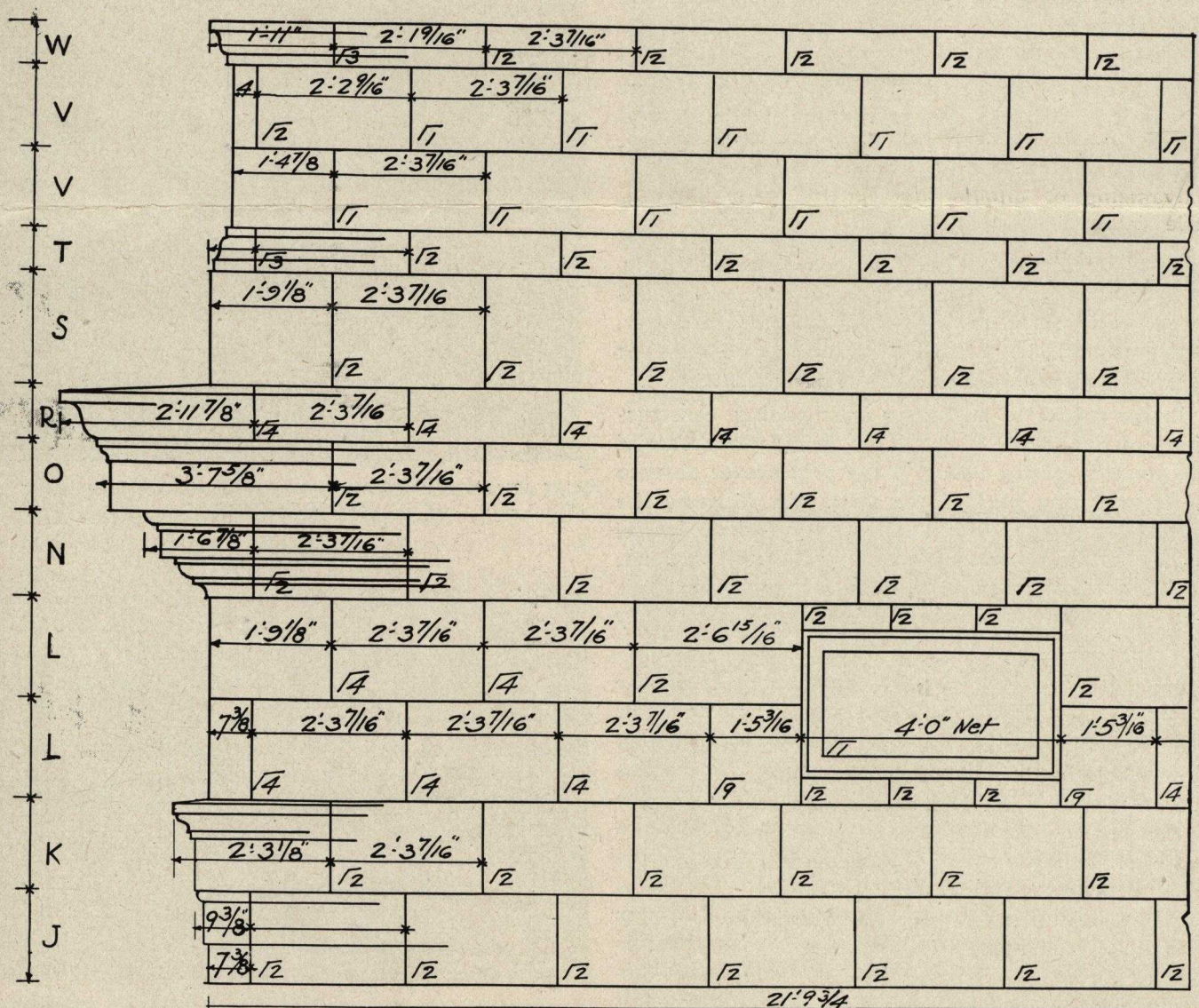


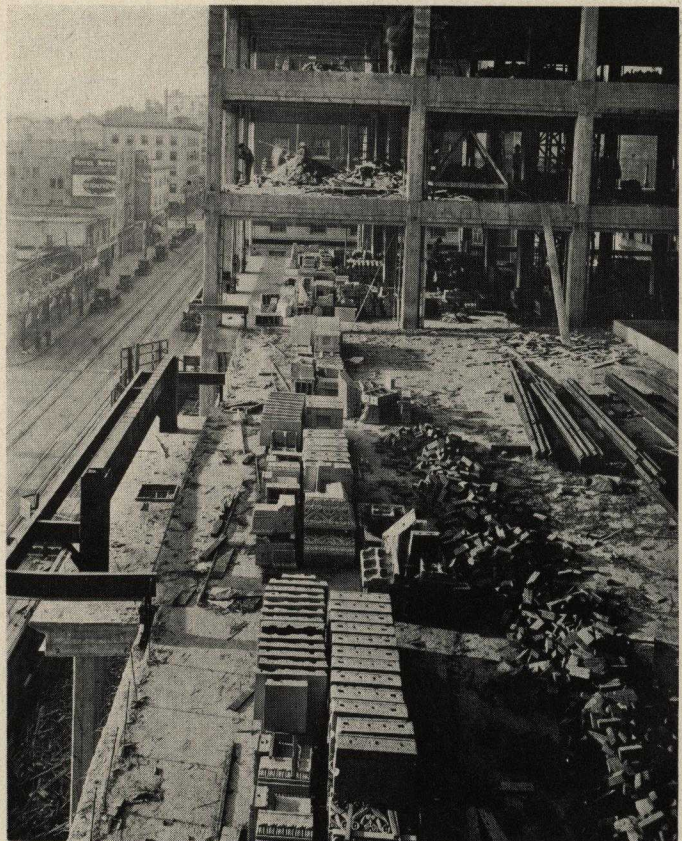
FIG. 2

Free-standing pieces as a rule are not filled. These are now generally made so that the successive sections are closed on top, with interlocking joints. It will be noted that each section of the baluster is closed on top and that the different sections interlock for security. This prevents the entry of water and imparts the necessary rigidity to the construction. Where for any reason anchor or tie rods are necessary in free-standing work, they should be of bronze, stainless steel, or other non-corroding metal.

This matter of the character of the anchors or tie rods is one of outstanding importance, not to terra cotta alone but to all types of masonry. The corrosion of anchors recently necessitated the removal and reconstruction of a great deal of the stonework on the houses of Parliament in England, and is a fruitful cause of trouble everywhere if disregarded. Steel, in rusting, expands to many times its former size, and in so doing, exerts a force that is disastrous to any kind of masonry in which it may be embedded. If anchors are protected so as to preclude definitely the possibility of water reaching them, iron anchors may be used, though even for such purposes the relatively slight additional cost of non-corroding metal is justified. For projecting work, such as gargoyles, cornices, etc., or for exposed situations, such as the rail of a balustrade, only bronze, stainless steel, udytited (cadmium plated) steel, everdur, or other assuredly non-corroding metals should be employed. Galvanizing or dipping in asphaltic paints are of little value.

On the Pacific Coast, where reinforced concrete is extensively used for the structural framework of all kinds of buildings, what is known as the "Davis" system of construction is sometimes employed. The face of the structural concrete is cast to form a series of recessed steps with anchor rods projecting. As the terra cotta is set, the mason slushes it full with what is really a concrete mortar, which keys into the recesses already provided, and is further anchored to the structure by means of tie rods engaging those previously left projecting from the concrete.

When facing reinforced concrete construction several methods may be employed to anchor the terra cotta which, except on the Coast as noted, is generally left unfilled. Metal keyways may be lightly attached to the forms at suitable intervals, so that when the forms are stripped the keyways are anchored in the concrete. Clips which are shaped to fit the keyway have a hole in them through which the anchor rods may be passed: see Fig. 5. As the clips can be placed in the vertical keyways at any point the system is very flexible. Otherwise, if wire anchors embedded in the concrete are not used, rods are left projecting from the face of the wall at suitable intervals, and after the forms have been removed, the projecting ends are turned up to engage and hold horizontal rods over which the anchor-irons are slipped, as shown in Fig. 4.



TERRA COTTA PILE ON THE BUILDING READY FOR MASONS TO SET



SETTING TERRA COTTA ON STEEL SHELF ANGLE ATTACHED TO COLUMN

Obviously, it is impossible to cover in detail anchoring methods to meet all conditions, but each terra cotta manufacturer is not only ready but anxious to place his experience in this connection at the contractor's disposal for their mutual interest.

The subjects of construction and anchoring unavoidably lap over into the field of keeping out water, as has already become apparent by this time. However, there are a number of points which relate particularly to the subject which might be considered here.

First, as to the terra cotta itself. As before stated, the manufacturer makes every effort in laying out the work, and in modeling and making his material, to make it difficult or impossible for water to get in. If, from experience, he knows that certain portions of the work or certain individual members are particularly subject to exposure, he provides weepers or little drainholes so that the water may run out or evaporate, and not accumulate, freeze, and injure the construction. Yet, as he does not set his material, he is dependent upon the mason contractor to see that joints are filled and that the weepers are not. Inspection of a piece of work taken down last year, where the penetration of moisture had caused trouble, showed that the masons had trodden flat the sheet metal scuppers which were to lead out any water which might penetrate behind the facing material, and then, in addition, had filled the drainways in back solidly with mortar. Two strands of No. 10 wire had been substituted for a $1\frac{1}{2} \times \frac{1}{2}$ inch band in each course of a circular structure, all nullifying the manufacturer's best efforts for durability.

An example of the study and progress made in the material itself is shown in Fig. 8. The drawing shows three different and successive types of sill or parapet joints. The first or roll joint was excellent in theory, but in practice it was found that the joint was a difficult one to get the masons to make tight, and hard to keep tightly pointed. The roll lip, too, was always susceptible to breakage, in handling, setting, or afterward. It was finally abandoned and the second type, with raised lips, adopted.

This design was more satisfactory, but again the masons' habits of work forced a change. When not closely supervised, the mason contented himself with buttering the edges of the piece, and in the event of stresses caused by temperature changes in the structure, they were concentrated on the lips which tended to shear off. It was also found that as long as the nature of the joint was such that it seemed likely to be water-resisting, the mason tended to slight his setting, depending on the design of the joint to make the job tight. As a result, the third type of joint, perfectly flush, was adopted and is now in use. With this joint, the mason realizes that water-tightness depends solely on his workmanship, and better results are obtained.

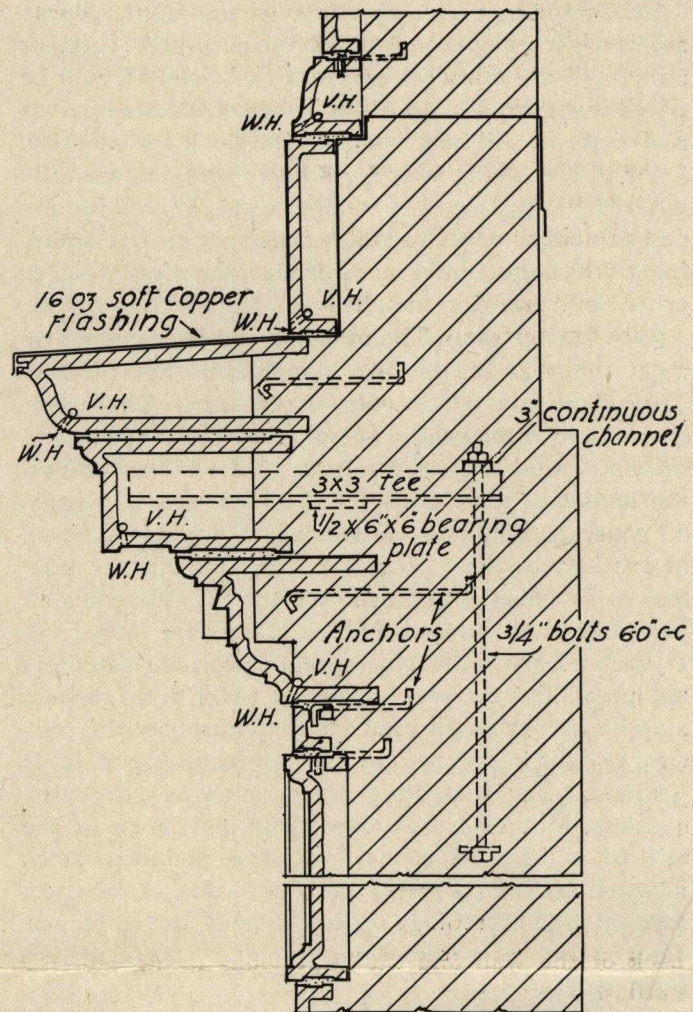


FIG. 3

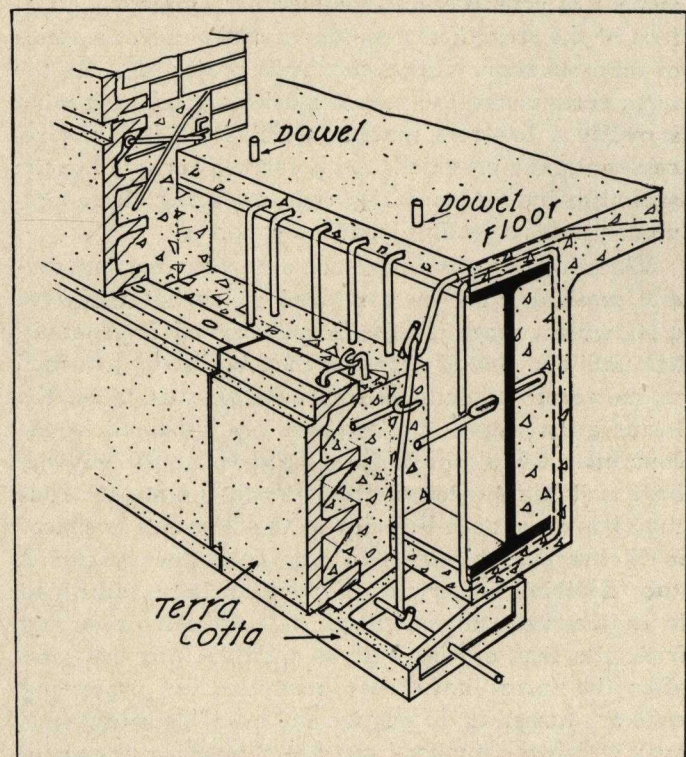


FIG. 4

On surfaces which are horizontal, or nearly so, reliance can be placed entirely on the mortar joint to make the wall tight. Shrinkage in the mortar often leaves hair-fine cracks through which water will penetrate, while movement in the structure and the ordinary processes of weathering still further impair joint tightness.

Cornices illustrate a point in the protection of wide, nearly flat, projecting members. The only sure method of making such construction tight is flashing the entire top surface. The metal should be carried down over the edge of the crown molding, and anchored. A drip should be formed on the lower edge of the flashing to keep water from draining down the face of the wall: see Fig. 3. Some of the photographs also show this detail.

Where the surface cannot be flashed on top, as in the case of a parapet coping, recourse may be had to the so-called elastic cements, but in no case should full reliance be placed only on the mortar joint.

Parapets are one of the most difficult features of a building, for any and all architectural materials. If the coping joints have not been made tight by the use of a water bar, elastic cement, or flashing, it is generally considered better not to waterproof the back of the parapet. If the back of the wall is left exposed, any moisture penetrating the wall through the coping joints or elsewhere is free to evaporate; otherwise the moisture is held between the waterproofing on the back of the wall and the impervious facing material until the saturation point is reached and damage results. In the event that the wall is left "open" as described, flashing should be placed the full width of the wall just above the roof level, the metal to be left projecting from the wall on the roof side as cap flashing to be turned down over and seal the base flashing.

If, however, the coping joints are definitely watertight, or if the parapet has been protected from leakage by carrying flashing across the width of the wall under the coping, then the back of the wall may be protected either by a membrane, plaster coat, or metal flashing. These details are shown in Fig. 6.

The dense impervious surface of terra cotta makes it extremely slow to acquire the coating of dust and grime which is inevitable in the average modern city. If, however, it is desired to restore newness of appearance it can be done easily by simple washing. Sand blast should never be used as it is both unnecessary and highly destructive. Based on the findings of its Research Fellowship at the Bureau of Standards, the National Terra Cotta Society recommends the following:

Cleaning agents for Terra Cotta may be classed as:

A. Strong Acid Cleaners:

1. 5% hydrofluoric acid
2. 15% hydrochloric acid

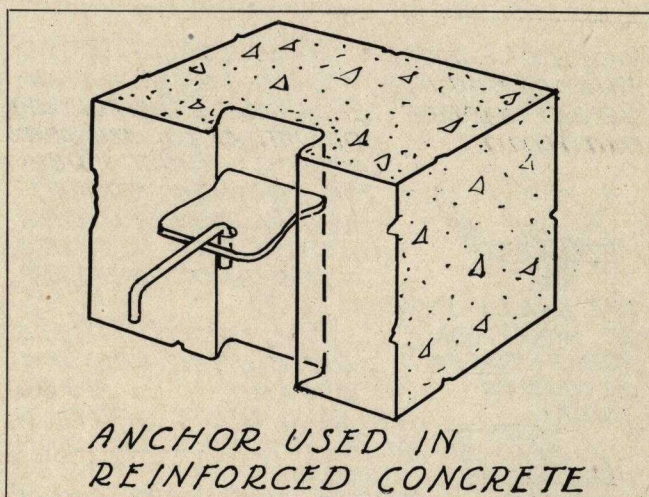


FIG. 5

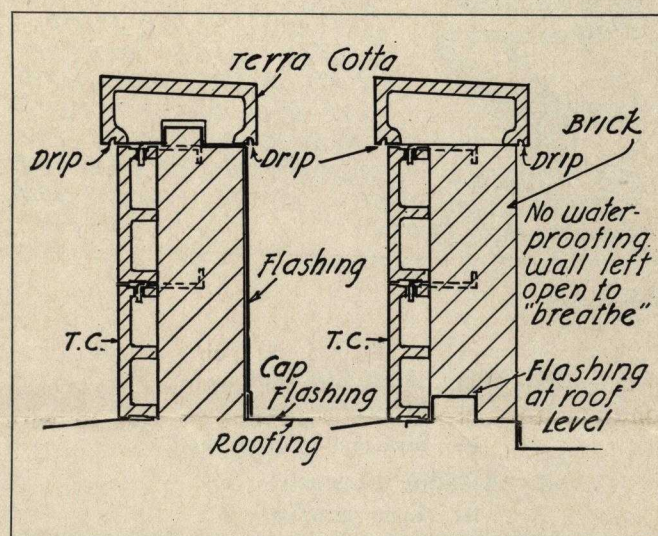


FIG. 6

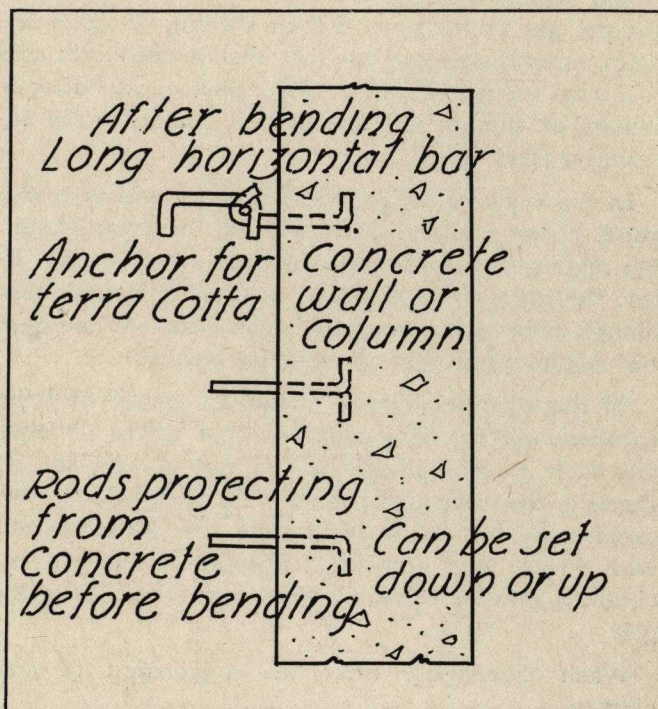
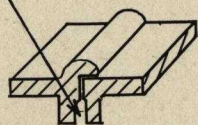
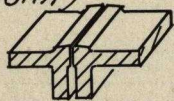


FIG. 7

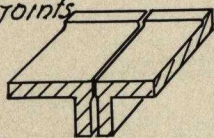
vertical joints seldom had sufficient mortar in them



THE EARLY TYPE OF WEATHER JOINT (The roll or covered joint)



THE LATER DESIGN (raised joints)



THE MODERN METHOD (the simple butt joint)

These covers were often broken by expansion of the building or split off by moisture freezing under them. The pointing mortar usually cracked and worked out leaving the joint exposed.

The raised fillets were often chipped or broken. Many masons were under a false impression and supposed that raised fillets kept water out of the joints. The consequence was that they did not fill the joint solidly with mortar. When butt joints are used the mason realizes automatically the importance of pointing the joints solidly with mortar.

FIG. 8

B. Weak Acid Cleaners:

1. Fluosilicic acid
2. Sodium hydrosulphite

C. Alkaline Cleaners:

1. Soap powder
2. Trisodium phosphate

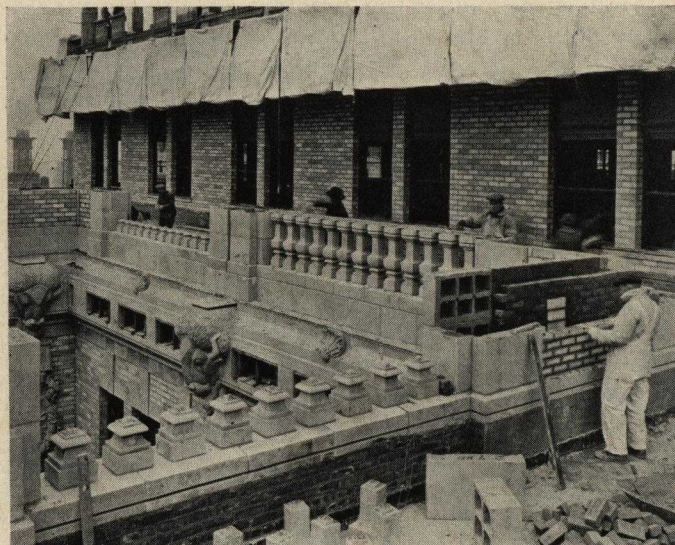
The strong acid cleaners are not recommended for general use on account of their etching of glaze finishes, notwithstanding the fact that hydrofluoric acid is a very efficient cleaner. The effect of the latter is somewhat, though to lesser degree, similar to the destructive sand blast.

In the weak acid cleaners, fluosilicic acid proved a good, cheap cleaner, especially for lustrous glazes. On matt glazed and unglazed terra cotta it may affect the glaze very slightly. Sodium hydrosulphite, though somewhat expensive, is most efficient and does not affect any of the various glaze finishes.

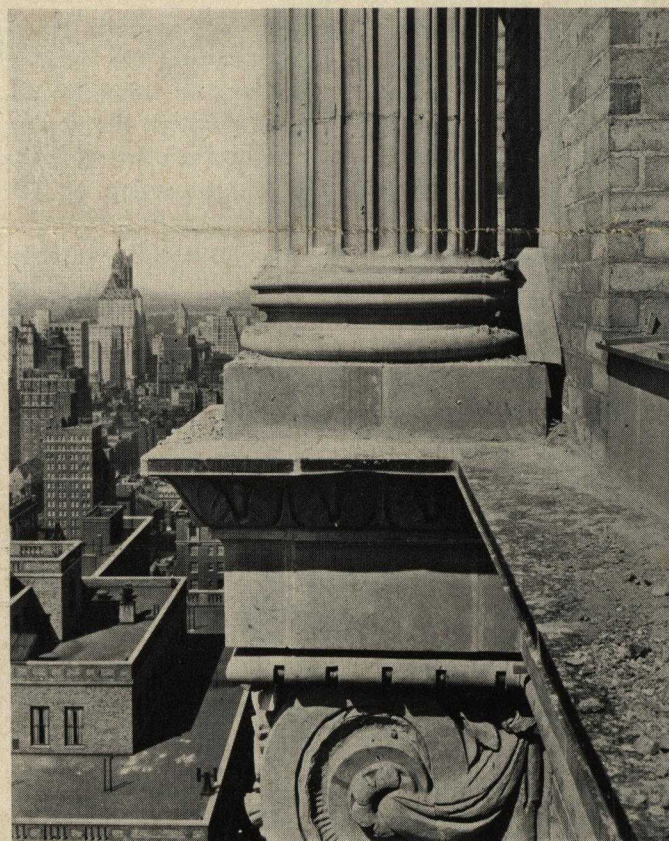
Of the alkaline cleaners, trisodium phosphate is an excellent cleaner for unglazed terra cotta. It does not etch glazed finishes but is not as efficient on glazes as the weak acid cleaners. Soap powders prove satisfactory for glazed terra cotta that is not coated with dirt of long standing. Care should be used to obtain a powder relatively free from sharp abrasive grit.

Wash thoroughly after the application of any cleaner.

Many features commend terra cotta to the builder.



SETTING TERRA COTTA BALUSTERS—NOTE EACH SECTION IS CLOSED ON TOP TO PREVENT THE ENTRY OF MOISTURE



COMPLETED CORNICE WITH ENTIRE UPPER SURFACE FLASHED WITH COPPER

Speedy and accurate preparation of shop drawings, highly organized production to avoid delaying the job, light weight, ease and economy of setting, adaptability to complicated structural conditions, and consistent research for the improvement of the product and its uses, all work to the general contractor's benefit.

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